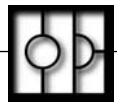

Research Article

Accelerometry-Determined Adherence to the *2008 Physical Activity Guidelines for Americans* among College Students

Douglas A. Raynor and Noelle M. Jankowiak

ABSTRACT

Background: *A need exists to determine whether college students engage in sufficient physical activity (PA) using objective methodology.* ***Purpose:*** *Accelerometry-based activity monitors were used to evaluate adherence to the U.S. Department of Health and Human Services' 2008 Physical Activity Guidelines for Americans.* ***Methods:*** *College students (N = 168) wore accelerometers for seven consecutive days.* ***Results:*** *The mean total minutes per day of moderate and vigorous PA were 53.9 minutes and 5.2 minutes, respectively, primarily via short intermittent bouts. When examining PA in bouts lasting the recommended minimum of 10 minutes, the average time spent per day in moderate and vigorous PA dropped to 12.5 minutes and 1.4 minutes, respectively. Thus, only 22.0% of the sample accumulated the recommended minimum of 150 minutes per week of sustained moderate-to-vigorous PA.* ***Discussion:*** *The findings suggest that college students intermittingly accumulate substantial moderate PA via lifestyle activities such as walking, but do not adhere to recommendations for prolonged moderate or vigorous PA.* ***Translation to Health Education Practice:*** *The results indicate that health education practitioners at the collegiate level should educate young adults about the increased efficiency and long-term health benefits of meeting PA recommendations by engaging in sustained moderate and vigorous activities.*

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BACKGROUND

Maintaining a physically active lifestyle confers a myriad of physical and mental health benefits, including significantly decreasing the risk of several leading causes of mortality and disability, such as cardiovascular disease, cancer and depression.[1] Moreover, lack of habitual physical activity (PA) has contributed considerably to the recent obesity epidemic that has affected all age groups in the United States.[1] In turn, the rise in obesity among today's youngest generation may contribute to the reversal of the continuous growth in life expectancy observed over the last century. As a result, members of the youngest generation today may, on average, experience greater morbidity and perhaps earlier mortality than their parents.[2]

Long-term adult health-behavior patterns are often established during the developmental transition period from childhood to adulthood.[3] A physically inactive lifestyle that develops during young adulthood (i.e., 18 – 25 years of age) may endure throughout the lifespan. Therefore, it is critical to determine whether one large group of young adults, college students between the ages of 18 to 22 years old, is engaging in sufficient PA. To gauge college students' PA engagement, it is necessary to make comparisons with public health recommendations. Over the past two decades, multiple national agencies have developed PA guidelines, with various degrees of frequency, intensity and duration, as a major component of health

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promotion and disease prevention strategies. Recently, the U.S. Department of Health and Human Services published the *2008 Physical Activity Guidelines for Americans*,[4] which suggest that adults aged 18-64 should engage in aerobic activity a minimum of 150 minutes per week of moderate-intensity PA, 75 minutes per week of vigorous-intensity PA, or an equivalent combination of moderate- and vigorous-intensity PA. Moderate-intensity is defined as PA performed at 3.0 to 5.9 times the intensity of rest (e.g., brisk walking), and vigorous-intensity is defined as PA performed at 6.0 or more times the intensity of rest (e.g., jogging or running). A caveat to the *2008 Physical Activity Guidelines* is that moderate or vigorous PA should be performed in bouts of at least 10 minutes to obtain the greatest health and fitness benefits.[4]

Past research suggests that American young adults are not engaging in sufficient PA. Multiple studies have confirmed that PA drops precipitously when high school graduates enter college[5,6] and sedentary activities increase.[7] In fact, two recent qualitative reviews of survey research suggest that only 35-60% of American college students are currently adhering to various recommended levels of PA.[8,9]

A significant limitation of the literature on college students' PA rates is that almost all studies have assessed PA with self-report measurement.[8,9] The accuracy of self-report is questionable given that respondents tend to over-report PA levels, particularly of vigorous intensity,[10] and self-reports are subject to recall bias, memory decay, and impression management.[11] In recent years, the increased affordability of objective measurement tools has led to their gradual adoption by PA researchers. Accelerometry-based monitoring has become one of the more respected and popular methods to objectively assess PA due to its large information storage capacity, noninvasive properties, and quantification of PA under field conditions.[12] Accelerometers are compact, durable devices worn on a belt close to the body, usually on the hip, that measure changes in velocity over time. The degree of acceleration is used to quantify frequency, duration and intensity of movement.[12] Accelerometry accurately estimates energy expenditure during human locomotion activities, such as walking or running, but may underestimate the energy costs associated with common household chores or lifestyle activities involving upper body movement (e.g., washing windows, dusting), bearing weight (i.e., pushing a gas-powered lawn mower), or ambulation on a slope.[13] The monitors are generally worn for several days to gather an accurate measurement of individuals' PA during daily life.[14]

Despite the relative advantages of accelerometry, researchers studying college students' PA levels have been slow to embrace this technology, possibly due to cost, subject burden and complexity of data management.[15] A few notable exceptions exist in the college student literature. Dinger and Behrens[16] examined PA in 454 college students and found that 53% of the participants accumulated 30 minutes or more of moderate PA on at least five days per week, and 4.6% accumulated vigorous PA for a minimum of 20 minutes at least three days per week. However, when data were examined in sessions lasting at least 10 minutes, almost all of the participants (96.3%) failed to meet the moderate-intensity PA recommendation. Sisson et al.[17] examined PA in 26 college students and determined that approximately 62% engaged in 30 minutes of moderate-intensity PA on most days of the week. On average, the students accumulated approximately 57.3 minutes per day of combined moderate/vigorous PA. However, the researchers did not report moderate and vigorous PA results separately, nor did they examine PA in bouts lasting at least 10 minutes. Troiano et al.[18] conducted one of the largest ($N = 6,329$) accelerometry-based studies to date with a nationally representative sample, albeit participants were recruited from communities rather than college campuses. They reported that PA levels decline during adolescence (ages 16-19) and early adulthood (ages 20-29), and continue to drop throughout the lifespan. When counting PA that accumulated in modified 10-minute bouts (i.e., at least 8 of 10 minutes met the intensity threshold), only 5.6% of participants ages 16-19 engaged in 30 or more minutes of combined moderate/vigorous PA on 5 of 7 days. Unfortunately, the authors reported PA adherence rates for all adults as a consolidated group between the ages of 20 to 59, which does not differentiate the traditional college age years of young adulthood (i.e., 18-22 years old) from the rest of adulthood.

A pedometer is another type of objective motion sensor that is inexpensive ($10-$50), simple to use, and feasible for measuring ambulatory PA by researchers and non-researchers alike. Although a pedometer cannot quantify duration of time spent at different PA intensities, such a device can be used to accurately assess the amount of daily activity in terms of steps per day. Moreover, pedometer users can self-monitor daily steps in real-time via a digital display window, which often motivates users to accumulate a designated number of steps per day.[19] Based on a comprehensive literature review, Tudor-Locke and Bassett[20] determined that 10,000 steps per day reasonably characterizes daily activity for healthy adults and promotes many health benefits.

To date, only three studies have examined college students' daily steps using pedometers. In a small study of 26 college students, Sisson et al.[17] reported that participants averaged significantly more steps per day on weekdays ($M = 9,527$) than on weekends ($M = 8,306$). In a larger study of 88 college students, Mestek et al.[21] reported that the mean steps per day were 9,318.5. Males ($M = 10,027$) accumulated significantly more daily steps than females ($M = 8,610$), and males (48%) were more likely to accumulate at least 10,000 steps per day than females (24%).[21] In a small study of 31 college students, Behrens and Dinger[22] reported that participants averaged 9,932 steps per day throughout a week, but they accumulated significantly more daily steps on weekdays ($M = 10,623$) than the weekend ($M = 8,205$).

Although steps are typically measured using pedometers, accelerometers have been shown to measure approximately the

same step counts as pedometers.[19] Accelerometers give an accurate record of steps at moderate and intense speeds during walking or running,[23] while maintaining the ability to evaluate energy expenditure, activity duration and intensity. The flexibility of accelerometer-based studies to assess both daily steps and time spent at various PA intensities is evidenced by the aforementioned PA study by Dinger and Behrens.[16] With the same sample and accelerometer-based methodology, these researchers reported time spent at various PA intensities and adherence to public health recommendations in one publication,[16] and reported the results on daily steps in a separate publication.[24] Students averaged 11,474 steps per day for the seven-day period, and 65% of females and 70% of males accumulated at least 10,000 steps per day.[24] Recently, Sisson et al.[25] examined Actigraph accelerometer-determined daily steps in 1,446 adults taking part in the 2005-2006 National Health and Nutrition Examination Survey. Results indicated that that the odds of having metabolic syndrome were 69% and 72% lower in men and women, respectively, averaging at least 10,000 steps per day than those averaging less than 5,000 steps per day.

PURPOSE

The primary purpose of the present cross-sectional, descriptive study was to determine objectively the proportion of students meeting public health recommendations applicable to college students, which currently are the *2008 Physical Activity Guidelines for Americans.*[4] In order to accomplish this objective, accelerometry-based activity monitors were used to assess PA levels over a seven-day period with a sample of students attending a college in the rural Northeastern U.S. Based on previous research findings, it was hypothesized that less than 50% of students would accumulate sufficient continuous moderate or vigorous PA to meet the guidelines. Given that most students walk to classes from on- or off-campus residences during the week, it was expected that more than 75% of the sample would accumulate at least 150 minutes of moderate PA in short, intermittent episodes that do not count toward fulfilling the current guidelines. Moreover, there is no published research assessing the number of daily steps necessary to achieve the current moderate and vigorous PA recommendations. Therefore, another objective of this study was to compare the *2008 Physical Activity Guidelines for Americans*[4] to the popular 10,000 daily steps recommendation.[20] It was estimated that those students meeting the PA duration/intensity guidelines would also accumulate the recommended 10,000 steps per day, primarily due to higher levels of moderate activities such as walking.

METHODS

Participants

Two-hundred undergraduate students were recruited from psychology courses at a medium-sized liberal arts college in rural upstate New York using online human subject pool management software called Sona Systems (Tallinn, Estonia). Regardless of their major, students were eligible if they were enrolled in a psychology course (primarily introductory psychology and other lower-division psychology courses) in which the instructor provided extra credit for participation in a psychological study. At the beginning of the spring 2006, fall 2006, and spring 2007 semesters, students were provided with directions orally by their instructors and in their syllabi on how to register for any of the active studies listed on the subject pool website. This study was approved by the college's Institutional Review Board.

Procedures

Participants attended an orientation session and a feedback session one week later. At the first session, participants provided written informed consent and were equipped with an ActiGraph GT1M accelerometer (ActiGraph LLC, Pensacola, Florida), which was to be worn on a belt around their hip for seven consecutive days. Participants were instructed to wear the accelerometer at all times, including sleep, with the exception of water activities (e.g., showering, swimming). At the second session on the eighth day, participants returned the accelerometer and the ActiGraph GT1M data were uploaded directly to a personal computer. Participants' height and weight were measured individually by a trained undergraduate research assistant in a private room with an electronic scale (Seca, Model 840, Hamburg, Germany) and a portable stadiometer (Seca, Model 216, Hamburg, Germany), respectively. Finally, participants received a printout and verbal explanation of their accelerometer results. Data were collected in 29 cohorts ranging in size from 3 to 10 participants between March 27, 2006 and December 5, 2007, excluding summers.

Instruments

In the present study, the ActiGraph GT1M model was used. Evidence suggests that the ActiGraph GT1M accelerometer and its predecessor models provide a valid assessment of ambulatory PA under laboratory and field conditions.[23,26,27] The ActiGraph GT1M converts accelerations into activity counts, which are summed in preset sampling periods, or epochs. The present study designated 1-minute epochs, which is customary in accelerometry studies of adults.[14] Using the ActiLife Lifestyle Monitoring System Version 3.2.0 software (Pensacola, FL), the intensity of PA was divided into four categories according to established activity count cutoff points: inactive (0-499 counts/minute), light (500-1951 counts/minute), moderate (1952-5724 counts/minute), and vigorous (>5724 counts/minute).[16,27-30] In addition to activity counts, the ActiGraph GT1M provides a valid measure of step counts.[23] Based on a review of seven accelerometry-based reliability studies with adults, Trost et al.[26] concluded that 3 to 5 days of monitoring is sufficient to achieve an adequate level of reliability (i.e., an intraclass correlation coefficient exceeding 0.80). However, given the regularly observed differences in PA between weekdays and weekend days among children and adults, a standard seven-day monitoring period is recommended for all age groups as a best practice for accelerometer-based PA research.[14] All of the ActiGraph GT1M

accelerometers were calibrated by the manufacturer prior to the study.

Based on recently recommended accelerometer compliance requirements,[14] participants were required to have worn the accelerometer at least 80% of available daily hours on at least five of seven days to be included in analyses. It was assumed that participants were not wearing the ActiGraph GT1M accelerometer when total activity counts per minute were zero for at least 60 consecutive minutes. Failure to comply with these parameters resulted in the exclusion of 25 participants. Moreover, data from 6 participants were lost due to mechanical failure of the ActiGraph GT1M accelerometers, and 1 participant did not return an accelerometer. The final sample size was comprised of 168 participants.

Statistical Analysis

All analyses were conducted using SPSS for Windows Version 16.0 (SPSS Inc, Chicago, IL). Descriptive data for activity counts, duration at various intensities, and steps were computed. For duration data, each 60-second epoch of activity counts was converted into minutes spent in inactive-, light-, moderate-, and vigorous-intensity categories, and then summed for each day. The daily mean number of minutes spent in each intensity category was calculated by dividing the total weekly number of minutes in each intensity category by the number of valid days of accelerometer compliance. Consistent with common practice, another intensity category combining moderate and vigorous PA categories, referred to as MVPA, was derived and reported. Given that the *2008 Physical Activity Guidelines for Americans*[4] stipulate that moderate and vigorous PA should be accumulated in bouts lasting a minimum of 10 minutes, duration data are presented for PA per day occurring in sessions lasting at least 10 or more consecutive minutes above the relevant intensity thresholds. For comparison purposes, total accumulated moderate and vigorous PA minutes were also computed irrespective of the 10-minute minimum. Mean steps per day were also computed for valid days. Since it is customary to examine sex differences in adherence to PA guidelines,[16-18,21,22,30] descriptive statistics are presented by sex and for the sample as a whole.

Associations among five variables—season, BMI, day of week, sex and residence location—and PA levels were examined using inferential statistics. In light of previous research showing PA tends to decline in winter months,[31] one-way analyses of variance (ANOVA) were computed to determine whether PA levels (daily time spent in MVPA in sessions ≥ 10 minutes and daily steps) significantly differed across the three seasons (fall, winter and spring) in which this study was conducted. Since some evidence suggests that PA levels are lower among overweight and obese individuals,[32-33] independent samples *t*-tests were computed to determine whether the aforementioned PA variables significantly differed between non-overweight (BMI < 25) and overweight (BMI ≥ 25) individuals. Also, prior research has shown that PA differs by day of the week.[16,17,22,30] As such, the patterning of PA throughout the week was examined to determine whether students were more physically active during weekdays (Monday – Friday), presumably when they regularly commute to classes by walking, than on weekend days (Saturday – Sunday). Specifically, paired samples *t*-tests were conducted to compare daily MVPA and daily steps between weekdays and weekend days. In order to reduce the overall number of analyses, data were split into two groups, weekday (Monday – Friday) and weekend (Saturday – Sunday), rather than comparing all seven days against each other. Since some evidence indicates that male and female college students may differ in their PA levels,[8,21] independent *t*-tests were performed to determine whether male and female participants varied on daily MVPA and daily steps. Moreover, students living in the college's campus residence halls invariably walk to classes, whereas many students living in off-campus housing (e.g., apartments in the nearby village) often commute to campus by car or bus. For this reason, the influence of residence location (campus residence hall vs. off-campus housing) on daily MVPA and steps was analyzed with independent samples *t*-tests.

Adherence to various PA recommendations was then examined. The proportion of the sample meeting the *2008 Physical Activity Guidelines for Americans*[4] was calculated by determining the extent to which students accrued 150 minutes of moderate- or 75 minutes of vigorous-intensity PA per week in sessions lasting at least 10 minutes. Next, the sample was partitioned into PA categories for healthy adults based on participants' daily steps, as recommended by Tudor-Locke and Bassett:[20] sedentary (<5,000 steps/day), low active (5,000-7,499 steps/day), somewhat active (7500-9,999 steps/day), active (10,000-12,499 steps/day), and highly active (≥12,500 steps/day). Chi-square tests for independence were computed to determine whether the proportions of participants meeting or not meeting the combined MVPA and steps recommendations significantly differed based on season, weight status, sex and residence location. Lastly, in order to guide future adherence to public health guidelines via pedometers, analyses were performed in order to determine the number of daily steps associated with achieving the intensity/duration goals delineated in the *2008 Physical Activity Guidelines for Americans.*[4] Specifically, independent *t*-tests were computed to determine whether the mean number of daily steps among participants meeting the *2008 Physical Activity Guidelines for Americans*[4] were significantly greater than those not meeting the PA recommendations.

All analyses excluded data from those days with insufficient wearing time. The *P*-value for all inferential tests was set at the 0.05 level.

RESULTS

Participants

Participants were predominantly female (60.1%), and white (77.4%) or Asian/Pacific Islander (11.9%). The mean age of the sample was 19.1 years (*SD* = 1.8), and the age range was between 18 and 23 years old. Seventy-two percent of the sample was in their first or second year of college. Ap-

proximately 80% of students lived in campus residence halls and 20% lived in various off-campus locations (e.g., apartments). The mean body mass index was 23.9 (*SD* = 3.7), with 69.0% and 30.4% of the sample classified as non-overweight and overweight, respectively. The number of valid days of accelerometer wear was high, with a mean of 6.6 (*SD* = .67) valid days; 10.1% of the sample had 5 valid days, 20.2% had 6 valid days, and 69.6% had 7 valid days. The average number of hours per day wearing the accelerometer was 23.09 (*SD* = 1.09).

Activity Duration

Descriptive statistics for PA levels are presented in Table 1. Overall, participants were inactive for an average of 1,260.1 minutes per day (*SD* = 44.1), and they spent an average of 96.0 minutes per day (*SD* = 27.4) in light PA. When considering accumulated time without the minimum bout duration, students averaged 53.9 minutes per day (*SD* = 22.5) in moderate PA, and 5.2 minutes per day (*SD* = 7.4) in vigorous PA. However, time spent in moderate or vigorous PA differed noticeably when examining sessions lasting at least 10 minutes. When this minimum duration was included, the average time spent per day in moderate and vigorous activity dropped to 12.5 minutes (*SD* = 12.2) and 1.4 minutes (*SD* = 4.6), respectively.

Inferential statistics were computed to assess the influence of season, BMI, day of the week, sex and residence location on daily MVPA time in sessions lasting at least 10 minutes. Results indicated that that the season, or specific time of year, was not significantly associated with MVPA (F (2,165) = 0.88, P = 0.44). Similarly, BMI was not significantly associated with daily time spent in MVPA (t (165) = 0.60, P = 0.55). To facilitate visual inspection, the amount of time spent in moderate and vigorous PA for each day of the week is depicted in Figure 1. Students engaged in significantly more MVPA (t (167) = 3.13, P = 0.002, d = .24) during weekdays (M = 13.44, *SD* = 14.20) than weekend days (M = 10.0, *SD* = 13.75). According to Cohen's[34] guidelines for interpreting size of effects, a d equal to .24 represents a small to medium effect size. Males and females did not significantly differ in MVPA (t (166) = -1.12, P = 0.27). Finally, the influence of residence location on MVPA was not statistically significant (t (166) = 1.18, P = 0.24).

Step Levels

The mean number of steps per day for the total sample was 9,808.32 (*SD* = 2,907.42). The influence of season on daily steps was not significant, (F (2,165) = 1.62, P = 0.20), nor was BMI significantly associated with daily steps (t (165) = 0.40, P = 0.97). Similar to the results observed with MVPA, students accumulated significantly more daily steps (t (167) = 6.60, P < 0.001, d = .51) during weekdays (M = 10,240.8, *SD* = 2,980.8) than weekend days (M = 8,536.7, *SD* = 3,935.4). This represents a medium effect size.[34] Males and females did not significantly differ in daily steps (t (167) = 0.83, P = 0.41). A significant effect of residence location was observed for daily steps (t (166) = 2.98, P = 0.003, d = .60), with students living in campus residence halls accumulating more daily steps (M = 10,143.4, *SD* = 2,934.9) than students living in off-campus housing (M = 8,535.1, *SD* = 2,443.4). This difference is a medium effect size.[34]

Adherence to Public Health Recommendations

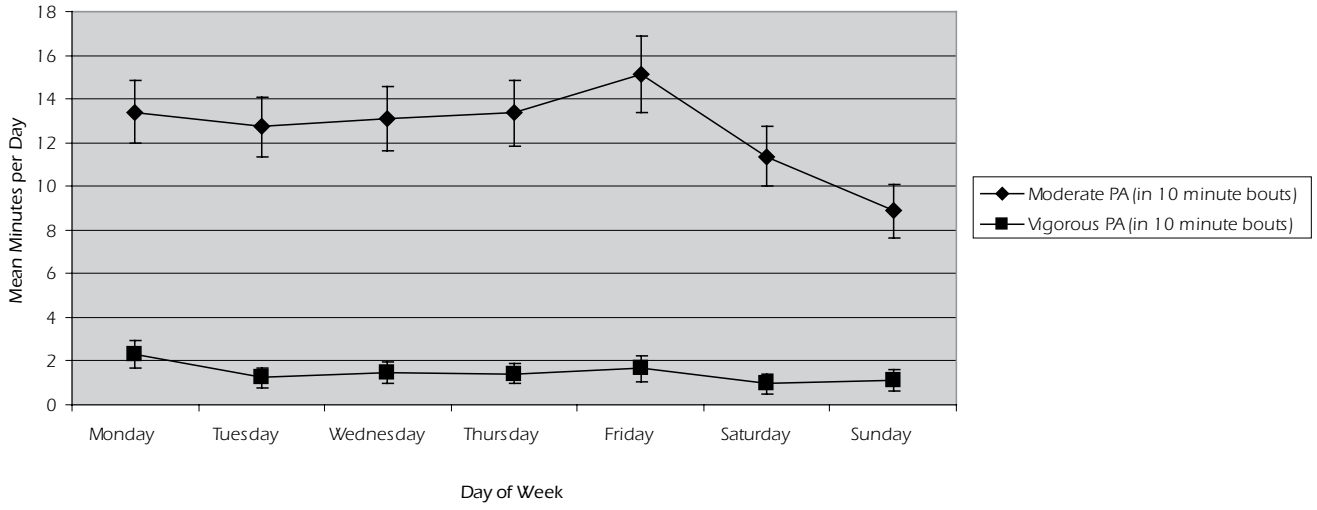
Moderate and Vigorous PA. The proportion of students adhering to the *2008 Physical Activity Guidelines for Americans*

Table 1. Descriptive Statistics of Physical Activity Counts and Time Spent in Various Intensities

Characteristic	Female (*N* = 101)	Male (*N* = 67)	Total (*N* = 168)
Mean activity counts			
Counts per day	351,037.47 (113,590.0)	386,431.36 (136,028.0)	365,152.89 (123,860.0)
Counts per minute	247.77 (80.00)	272.26 (94.97)	257.54 (86.84)
Mean time counting every minute (no minimum bout duration)			
Inactive minutes per day	1,258.49 (45.04)	1,262.42 (42.81)	1,260.06 (44.08)
Light minutes per day	97.96 (28.02)	93.03 (26.46)	95.99 (27.43)
Moderate minutes per day	52.85 (22.18)	55.45 (23.13)	53.88 (22.53)
Vigorous minutes per day	4.10 (6.27)	6.85* (8.55)	5.19 (7.37)
Combined moderate/vigorous minutes per day	56.95 (24.57)	62.29 (26.38)	59.08 (25.37)
Mean time from bouts lasting ≥ 10 minutes			
Moderate Minutes per Day	11.81 (12.09)	13.63 (12.28)	12.54 (12.17)
Vigorous Minutes per Day	1.19 (3.40)	1.78 (5.99)	1.43 (4.60)
Combined Moderate/Vigorous	13.01 (12.87)	15.41 (14.71)	13.96 (13.64)

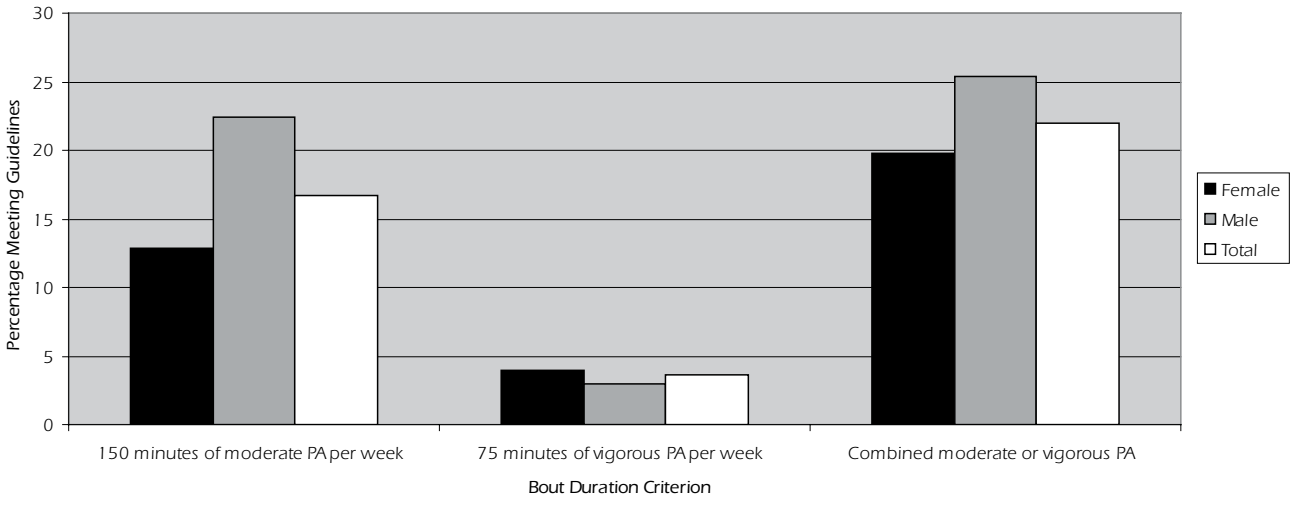
Notes: *P< 0.05 (based on an independent t-test). Values are means and standard deviations (within parentheses).

Figure 1. Mean Minutes Per Day in Moderate and Vigorous Physical Activity (PA) in Bouts Lasting at Least 10 Minutes*



*Values are means ± standard errors

Figure 2. Prevalence Adhering to the *2008 Physical Activity Guidelines for Americans*



was examined next (Figure 2). When participation was examined in bouts lasting at least 10 minutes, 16.7% of the sample accumulated at least 150 minutes per week of moderate PA, 3.6% accumulated at least 75 minutes per week of vigorous PA, and 22.0% accumulated at least 150 minutes per week of combined moderate or vigorous PA. Chi-square tests for independence indicated that adherence to the combined MVPA recommendation did not significantly differ across seasons ($\chi^2(2) = 0.01$, $P = .99$), BMI categories ($\chi^2(1) = 0.87$, $P = 0.35$), sexes ($\chi^2(1) = 0.73$, $P = .39$), and residence locations ($\chi^2(1) = 0.11$, $P = 0.75$).

Steps. Consistent with recommendations by Tudor-Locke and Bassett,[20] the sample was categorized into five groups based on the number of daily steps: sedentary, 3%; low active, 18.5%; somewhat active, 35.7%; active, 29.2%; and highly active, 13.7%. Thus, a minority of participants (42.9%) exceeded the recommendation of accumulating at least 10,000 steps per day. Chi-square tests for independence revealed a lack of significant differences across the step categories for seasons ($\chi^2(8) = 6.85$,

$P = 0.55$), BMI categories ($\chi^2(4) = 3.31$, $P = 0.51$), and sexes ($\chi^2(4) = 1.22$, $P = 0.88$). However, a significantly higher proportion of students living in campus residence halls (46.6%) adhered to the 10,000 steps per day guidelines than students living in off-campus housing (28.6%) ($\chi^2(4) = 11.32$, $P = 0.02$, Cramer's $V = .26$). According to Cohen's guidelines,[34] the influence of residence location is a medium effect.

Number of Daily Steps Associated with Adherence to Physical Activity Recommendations

Students adhering to each of the *2008 Physical Activity Guidelines for Americans*[4] accrued significantly more steps than those students failing to adhere. Participants who met the moderate PA goal accumulated significantly more daily steps ($M = 13{,}038.49$, $SD = 3{,}008.43$) than those who did not adhere to this guideline ($M = 9{,}162.29$, $SD = 2{,}423.97$) ($t(166) = -7.41$, $P < 0.001$, $d = 1.42$). Those meeting the vigorous PA goal also accumulated several thousand daily steps more ($M = 14{,}116.10$, $SD = 3{,}416.01$) than non-adherers ($M = 9{,}648.78$, $SD = 2{,}772.82$) ($t(166) = -3.85$, $P < 0.001$, $d = 1.44$). Lastly, students meeting the combined MVPA recommendation accumulated significantly more steps ($M = 13{,}101.28$, $SD = 2{,}741.05$) than non-adherers ($M = 8{,}878.25$, $SD = 2{,}195.54$) ($t(166) = -9.76$, $P < 0.001$, $d = 1.70$). All three of these effect sizes are considered large.[34]

DISCUSSION

The *2008 Physical Activity Guidelines for Americans*[4] stipulate that moderate or higher-intensity PA should be accumulated in episodes lasting at least 10 minutes. When computing descriptive statistics including this minimum duration criterion, students averaged only 14 minutes per day of combined MVPA. As such, only 17% of students met the moderate PA goal, only 4% met the vigorous PA goal, and only 22% met the combined MVPA goal. Overall, the present findings are highly comparable to the PA patterns observed in other accelerometer-based studies of college students' PA.[16,17] For instance, students in the Dinger and Behrens[16] study averaged 14 minutes per day of MVPA, and only 4% of students met the moderate PA recommendation.[16]

Another finding in the present study was that students engaged in significantly more moderate and vigorous PA on weekdays than on weekends. This day-of-the week finding replicates those from other studies conducted with college students using motion sensors.[16,17,22] Moreover, students living in campus residence halls averaged 1,308.2 more daily steps than students living in off-campus housing, who are more likely to commute to campus via automobile or bus. Taken together, these results support the idea that students' high level of moderate PA accumulated intermittingly is likely due to ambulatory commuting on weekdays.

Students averaged 9,808 steps per day across the seven-day period, and averaged significantly fewer steps on the weekend than weekdays. For the most part, the results are consistent with findings derived from other motion sensor-based studies of college students.[17,21,22,24] Results indicated that a minority of participants (43%) in the present sample accumulated sufficient daily steps to meet the recommendation of 10,000 steps per day, which approximates the proportion of students (36%) meeting this goal in the study by Mestek et al.[21] However, participants in the present study averaged 1,666 fewer daily steps than students in the Behrens and Dinger[24] study and 1,486 fewer daily steps than students at the residential campus in the Sisson et al.[17] study. This discrepancy may be due to the fact that the present study took place on a smaller campus in a colder region of the country and PA was assessed for several participants during colder months (November through March) when PA rates tend to decline.[31]

Students in the present study meeting any of the three intensity goals outlined in the *2008 Physical Activity Guidelines*[4] accumulated between 3,360 – 4,223 more steps per day than those failing to meet these goals. It is noteworthy that the average number of daily steps among students meeting the *2008 Physical Activity Guidelines* exceeded the typical recommendation of accumulating 10,000 steps per day by a couple of thousand steps per day, ranging from 2,157 for the moderate goal to 3,101 steps for the MVPA goal. The daily steps findings may serve as initial benchmarks for college students striving to meet current PA guidelines based on intensity/duration parameters.

The results of the present study have several implications for college students' current and future health. Most students accumulated a substantial amount of moderate PA each day in intermittent bouts, presumably via walking around campus and the surrounding town. Unfortunately, as demonstrated in this study, intermittently accumulating moderate PA does not translate for many individuals into adherence to the *2008 Physical Activity Guidelines*. Engaging in PA at higher intensities and for longer durations should yield greater benefits than accumulating moderate PA intermittingly throughout the day.[36] In the present study, the lack of sustained MVPA in bouts lasting at least 10 minutes suggests that the majority of college students (i.e., 78% in the current sample) are not receiving the maximum cardiorespiratory fitness and preventive health benefits that may result from sufficient PA.[1] For example, in a comprehensive review of existing epidemiological and experimental studies, Murphy, Blair and Murtagh[37] recently concluded that accumulating multiple bouts of at least 10 minutes of moderate or vigorous PA on most days of the week for at least four weeks improves cardiovascular fitness (i.e., VO_{2max}), lowers blood pressure, reduces body mass and adiposity, reduces waist and hip circumference, and increases high-density lipoprotein cholesterol. These reviewers concluded that further research is necessary to determine if accumulated bouts lasting less than 10 minutes actually provides significant health benefits.[37]

Given that the many traditional-age college students are not yet chronically unfit or inactive, it is arguable that reinforcing them for intermittingly accumulating a high quantity of lifestyle-based moderate PA may "lower the bar" for them and sacrifice the potential long-term preventive benefits of consistent engagement in sustained PA.[36]

Moreover, if young adults fail to adopt a consistent pattern of moderate or vigorous PA engagement during this critical formative period, evidence suggests that they are less likely to do so in subsequent years.[38,39]

Limitations and Directions for Future Research

Accelerometers provide rich objective data on PA, and as such, the use of this methodology should be considered a relative strength of the present study. However, this measurement strategy does have some limitations. For instance, accelerometers cannot determine the specific PA behaviors that students completed, and as such, it is not possible to test the assumption that the observed high amount of intermittent moderate PA was due in large part to walking. Also, since this type of motion sensor detects vertical accelerations at the hip or waist, they do not effectively estimate PA during certain types of non-locomotive activities involving gross arm and leg movements, such as cycling, rowing, and weight lifting.[12,13] ActiGraph accelerometers are not water-proof and need to be removed during water activities, so this assessment approach may also underestimate PA levels for individuals who participate in swimming and other aquatic activities. Also, since the newest generation of the ActiGraph accelerometer (Model GT1M) was used in the present study, caution should be exercised when making comparisons with findings derived from prior versions of the ActiGraph, other types of accelerometers, and pedometers. Recent research[23,35] suggests that the accelerometer used in the present study may be less sensitive to low-intensity steps than the previous generation ActiGraph Model 7164 used in the Behrens and Dinger[24] study and the Yamax SW-200 pedometers worn in the Sisson et al. study.[17] Therefore, the relatively lower estimation of steps per day in the present study is not unexpected, as the lower sensitivity of the Actigraph GT1M model would fail to register some steps at light-intensity that would accrue using more sensitive measuring instruments. As a result, the present daily steps findings may be conservative estimates. Additional research is necessary to interpret steps recommendations across motion-sensor devices. Lastly, it is possible that students who self-selected to participate in this study were more interested in PA than those who chose not to participate. If so, levels of PA in the present study may be higher than would be observed in a more representative sample of college students.

To the best of our knowledge, the present study is only the third to assess PA levels in college students using accelerometers. The first two studies were conducted at large universities in the Southwest[17] and South Central[16] regions of the U.S. where winters are mild and the topography is relatively flat. In contrast, the present study was conducted during three distinct seasons (fall, winter and spring) at a medium-sized liberal arts college in rural upstate New York. The campus is located on hilly terrain that can be hazardous during the extended cold season. Despite the differences in geography and campus size, the results across studies were highly consistent in demonstrating that most students successfully accumulate sufficient moderate PA in an intermittent manner but do not engage in sustained MVPA. In comparison to previous accelerometer-determined PA studies,[16,17] the institution where the present study took place is smaller, and with one notable exception,[16] the present sample size (N = 168) was larger than those used in previous college student studies (range of N = 26 to 88)[17,21,22] utilizing objective measures of PA. Additional accelerometer-based research conducted at heterogeneous locations and institutions will provide a more comprehensive evaluation of college students' objective PA levels and adherence to current PA recommendations.

Given the increased prevalence and documented efficacy of utilizing step counts in public health campaigns on college campuses[40] and a variety of other settings,[41] future research is necessary to replicate the present findings documenting the number of steps associated with college students meeting the *2008 Physical Activity Guidelines for Americans*[4] and other relevant PA recommendations. Finally, an area for future research is to examine the health-related sequelae of various durations and intensities of PA throughout students' undergraduate tenure. For instance, it is important to examine the relative efficacy of intermittent accumulation of lifestyle PA versus sustained vigorous PA in the prevention of weight gain and other deleterious metabolic changes to blood pressure, cholesterol profile and insulin sensitivity.

TRANSLATION TO HEALTH EDUCATION PRACTICE

The transition from high school to college is an important developmental period during which young adults develop greater autonomy for lifestyle and health behavior decision-making. This time period provides opportunities for health educators and campus communities to positively influence PA behaviors in their students. The academic, physical and social environment of college campuses may be uniquely suited to promote adoption and maintenance of PA. Results from this study suggest that students on this residential campus engage in a significant amount of intermittent moderate PA, especially on weekdays. Although students' ambulatory commuting should be reinforced, health promotion efforts at the collegiate level should emphasize strategies for meeting public health recommendations by engaging in sustained bouts of PA at the moderate- and vigorous-intensity level on both weekdays and weekends.

Several empirically-supported strategies exist for promoting PA in this population. A few PA interventions have successfully intervened with credit-based physical or health education classes emphasizing either self-regulatory behavioral skills (e.g., self-monitoring, goal setting, problem solving and relapse prevention)[42,43] or PA homework.[44] Other PA intervention studies with college students have modified the physical or social environment on campuses. For instance, one successful intervention provided a program of PA classes available free to students on campus, as well as activity demonstrations, fitness assessments, vouchers to a nearby pool, and on-campus media promotion.[45]

Another effective intervention provided students with services from a certified personal trainer over the course of a semester.[46] Finally, the Internet has proven to be a highly convenient and accessible medium for successfully enhancing college students' PA engagement. One study enhanced students' PA with social-cognitive theory-based e-mails, a website, access to an e-counselor and access to computer-mediated exercise materials.[47] Another web-based study increased PA using a buddy system and a commercial on-line logbook.[48] Given the poor adherence to the *2008 Physical Activity Guidelines* observed in the present study, health educators should consider implementing one or more of these interventions to enhance PA levels among college students on their campuses.

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